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09/869683

JC18 Rec'd PCT/PTO 03 JUL 2001

SPECIFICATION

METHOD OF PERMANENTLY COMPRESSING LUMBER AND COMPRESSED LUMBER

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FIELD OF THE INVENTION

The present invention relates of a method of permanently compressing lumber and compressed lumber, more precisely relates to a method of permanently compressing lumber, in which the lumber is compressed and heated, and compressed lumber, which is formed by compressing and heating porous lumber whose fine holes are formed by pine bark and wood borers, etc..

BACKGROUND TECHNOLOGY

Conventionally, compressed lumber, whose hardness is nearly equal to that of lumber of broadleaf trees, is formed by the steps of: compressing lumber of needle-leaf trees, etc.; and heating the compressed lumber by introducing wet steam into a container, in which the compressed lumber has been accommodated.

However, a pressure container is required so as to heat the lumber by the wet steam, so it is difficult to simultaneously heat a large amount of lumber in a large pressure container, and manufacturing efficiency must be low.

To solve the problems, Japanese Patent Gazette No. 7-47511 disclosed a method of permanently compressing lumber, in which raw lumber, whose percentage of water content is about 20 %, is compressed in a compressing die, then the compressed lumber is air-tightly accommodated in a container, with clearance between the compressed lumber and inner faces of the container, and heated; and Japanese Patent

Gazette No. 7-88810 disclosed a method of permanently compressing lumber, in which side faces of lumber is restrained by a jig, the lumber is compressed in a high temperature-high humidity atmosphere, then the compressed lumber is dried.

DISCLOSURE OF THE INVENTION

In the conventional method, the wet steam is introduced into the pressure container accommodating the compressed lumber; in the methods disclosed in the Japanese Patent Gazettes, a compressed state of the lumber can be fixed, in a short time, by wet-heating the compressed lumber with water included in the lumber, so that the compressed lumber can be formed in a simple facility.

However, in the methods disclosed in the Japanese Patent Gazettes, the compressed lumber must be air-dried.

In the method disclosed in the Japanese Patent Gazette No. 7-47511, the compressed lumber still includes 20 % of water. Thus, the lumber for houses or furniture must be air-dried until the percentage of water content reaches 12 % or less, but the lumber is apt to deform while the lumber is dried.

In the method disclosed in the Japanese Patent Gazette No. 7-88810, the lumber is accommodated in an air-tight place and compressed in the high temperature-high humidity atmosphere, then the air-tight condition is broken so as to compress the lumber while the lumber is dried. When the air-tight condition is broken, steam is apt to jet out if temperature is too high, therefore temperature of the lumber must be carefully controlled.

When raw lumber is compressed, water and contents in the lumber are pressed out from a cut end of the lumber with bad smell, so the waste water must be properly treated. By treating the waste water,

manufacturing cost of the compressed lumber must be higher.

These days, pine bark and wood borers, etc. damage trees, so that many fine holes are formed in an edge portion of damaged wood and density of the damaged wood is very low. Thus, the damaged wood are destroyed by fire or sterilized and exposed to wind and rain, therefore the damaged wood have not been effectively used as lumber.

To give various properties, e.g., durability, fire-registivity, to the lumber, various kinds of functional additive are impregnated in the lumber, but a specific facility is required, so that the lumber including the functional additive cannot be formed easily.

A first object of the present invention is to provide a method of permanently compressing lumber, in which the lumber is permanently compressed by compressing and heating the lumber without a drying step.

A second object is to provide a method of permanently compressing lumber, in which porous lumber having many fine holes, which are formed by pine bark and wood borers, etc., is compressed to make useful lumber, and compressed lumber formed by the method.

A third object is to provide compressed lumber including the functional additive.

The inventors of the present invention have studied to achieve the first object, they found the first basic structure, in which air-dried lumber, whose percentage of water content is 12 % or less, can be permanently compressed, as useful lumber, by compressing and heating without drying.

Namely, the first basic structure is the method of permanently compressing lumber comprising the steps of: compressing the lumber; and heating the compressed lumber, characterized in, that the lumber is air-dried lumber, whose percentage of water content is 12 % or less, the air-dried lumber is accommodated in a compressing die and contacts an

inner face of the compressing die, the air-dried lumber is compressed in the compressing die with compressibility of 50 % or more, and that the compressed lumber is air-tightly accommodated in the compressing die and heated so as to permanently compress the lumber.

In the method, the percentage of water content of the air-dried lumber may be 5 % or more, and the compressibility may be adjusted so as to make specific gravity of the compressed lumber 0.8 or more; with this method, flexural rigidity of the lumber can be equal to or greater than that of pure aluminum.

In the method, the compressing die, in which the compressed lumber is air-tightly accommodated, may be dry-heated; with this method, a pressure container, which accommodates and heats the compressing die, is not required.

The inventors of the present invention have studied to achieve the second object, they found that the damaged wood, in which many fine holes formed by pine bark and wood borers, etc. are formed in an edge portion and whose density is low, can be compressed, and suspension, which is formed by suspending the functional additive in alcohol, etc., can be easily absorbed into the fine holes, so that the second and the third basic structures have been found.

Namely, the second basic structure of the present invention is the method of permanently compressing lumber comprising the steps of: compressing the lumber; and heating the compressed lumber, characterized in that the lumber is porous lumber, whose fine holes are formed by pine bark and wood borers, etc., the porous lumber is accommodated in a compressing die and compressed, and that the compressed lumber is heated so as to permanently compress the lumber.

The third basic structure of the present invention is the permanently compressed lumber, which is formed by compressing and

heating porous lumber whose fine holes are formed by pine bark and wood borers, etc., having flexural rigidity of 130 MPa or more.

In the method of the second basic structure, compressibility of the compressed lumber may be adjusted so as to make flexural rigidity of the compressed lumber 130 MPa or more; with this structure, the flexural rigidity of the lumber can be equal to or greater than that of beech or zelkova lumber.

In the method, the lumber may be compressed while the lumber is heated in the compressing die; with this structure, the lumber can be easily permanently compressed. Especially, if the compressed lumber is dry-heated and a non-contact face of the lumber, which is not contact an inner face of the compressing die, is exposed in the air, the compressing die can be simpler and easily made.

Further, if the functional additive is filled in the fine Holes of the porous lumber, the compressed lumber can have Various properties.

The inventors of the present invention have further studied to achieve the third object, and they found that the damaged wood can be easily compressed, and the suspension, which is formed by suspending the functional additive in alcohol, etc., can be easily absorbed into the fine holes, so that the fourth basic structure has been found.

Namely, the fourth basic structure is the permanently compressed lumber, which is made by compressing and heating porous lumber having fine holes formed by pine bark and wood borers and whose fine holes are filled with the functional additive.

In the method of the second basic structure, if the compressibility of the compressed lumber is adjusted so as to make the flexural rigidity of the compressed lumber 130 MPa or more, the flexural rigidity of the compressed lumber can be equal to or greater than that of beech or zelkova lumber.

In the method, if the lumber may be compressed while the lumber is heated in the compressing die, the lumber can be easily permanently compressed. Especially, if the compressed lumber is dry-heated and the non-contact face of the lumber, which is not contact the inner face of the compressing die, is exposed in the air, the compressing die can be simpler and easily made.

Further, if the functional additive is filled in the fine Holes of the porous lumber, the compressed lumber can have various properties.

Note that, vessels and tracheids of wood are not included in the "fine holes" in the present invention.

In the first basic structure, the lumber to be compressed is air-dried lumber, whose percentage of water content is 12 % or less. No free water exists in cells of the air-dried lumber; combined water is combined with cell membrane thereof. In the present invention, the lumber is air-tightly accommodated by the compressing die and closing members, which close cut ends of the lumber, then the lumber is compressed and heated, thus the combined water, which is combined with cell membrane, can be used as water for wet-heating the lumber, and the lumber can be permanently compressed in a short time.

Namely, volume of spaces in cells of the lumber are reduced with increasing the compressibility of the lumber. If amount of the combined water in the compressed lumber, whose volume is reduced, is enough for producing wet steam while the lumber is heated, the compressed state of the lumber can be permanently fixed. Even if the percentage of water content of the air-dried lumber is made lower with increasing the compressibility of the lumber, the compressed state of the lumber can be permanently fixed.

By employing the method of the first basic structure, the lumber can be permanently compressed, as useful lumber, by compressing and

heating the lumber without the drying step.

In the second and the third basic structures, the lumber is the porous lumber, whose fine holes are formed by pine bark and wood borers, etc., but the edge portion including many fine holes and having lower density can be tightly compressed, so that the flexural rigidity of the compressed lumber can be equal to or greater than that of zelkova lumber. Therefore, the damaged porous wood, which was regarded as disused wood, can be effectively used as lumber.

Further, in the fourth basic structure, the suspension, which is formed by suspending the functional additive in alcohol, etc., can be easily absorbed into the fine holes of the damaged wood, so that the compressed lumber having various properties can be manufactured by compressing and heating the porous lumber, whose fine holes have been previously filled with the functional additive.

BRIEF DESCRIPTION OF THE DRAWINGS

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Fig. 1 shows the steps of the method of permanently compressing lumber of the present invention; Fig. 2 shows the steps of the method of permanently compressing lumber; Fig. 3 is an ordinary graph of compressibility of lumber; Fig. 4 is an explanation view showing a relationship between heating time and flexural rigidity of lumber; Fig. 5 is an explanation view showing a steam curve in a heating step; Fig. 6 is a graph showing results of a boiling test of a wooden plate, which, is formed by compressing and heating lumber damaged by pine bark and wood borers; Fig. 7 is a graph showing results of flexural test of the wooden plate, which is formed by compressing and heating lumber damaged by pine bark and wood borers; Fig. 8 is a graph showing a relationship between heating time and form-recovery rate of a wooden plate, which is cut from an edge portion of white birch lumber; and Fig. 9

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is a graph showing a relationship between heating time and the form-recovery rate of a wooden plate, which is cut from a core portion of cypress lumber.

PREFERRED EMBODIMENTS OF THE INVENTION

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An embodiment of the method of permanently compressing lumber of the present invention will be explained with reference to Figs. 1 and 2. In Fig. 1 and 2, air-dried lumber 10 shown in Fig. 1A is employed as lumber. Percentage of water content of the air-dried lumber 10 is 12 % or less, preferably 5 % or more.

Rectangular wooden plates 12 are formed by cutting the air-dried lumber 10 [see Fig. 1B], then the rectangular wooden plate 12 is compressed by a compressing die 14 [see Figs. 1C-1E]. The compressing die 14 includes: a female die section 16 having a concave portion 17, in which the wooden plate 12 is accommodated; and a male die section 18 for compressing the wooden plate 12 in the concave portion 17.

As shown in Fig. 1C, a bottom face and both side faces of the wooden plate 12 accommodated in the concave portion 17 of the female die section 16 contact inner faces of the concave portion 17 without gap; an upper face of the wooden plate 12 contacts a lower pressing face of the male die section 18 without gap.

In some cases, cut-end faces (growth-ring faces) of the wooden plate 12 may be exposed in the air. The wooden plate 12 is not substantially extended, in the axial direction, by compressing. By exposing the cut-end faces of the wooden plate 12 in the air, a structure of the compressing die 14 can be simpler.

The wooden plate 12 accommodated in the concave portion 17 of the female die section 16 of the compressing die 14 shown in Fig. 1C is compressed by the male die section 18 [see Fig. 1D]. The compressing

action is stopped when compressibility of the wooden plate 12 reaches a prescribed value, then compressed lumber 20 is formed [see Fig. 1E].

The desired compressibility depends on kinds of lumber, but it should be 50 % or more.

Ordinary compressibility of the lumber 12 is varied as shown in Fig. 3; at the beginning of the compression (zone "A"), the compressibility is suddenly made high with small compressing force. In the zone "A", collapsion, in which a part of a cell is broken, is propagated; by further compressing the lumber, the compressibility goes into a zone "B", in which the compressibility cannot be easily made higher with greater pressing force. In the zone "B", cells of the lumber are compressed and density thereof is suddenly made high. To make the compressed lumber 20 having high density (great specific gravity), the compressibility should reach the zone "B". The compressibility in the zone "B" depends on kinds of lumber. For example, minimum compressibility in the zone "B" of white birch lumber is 50 %; larch lumber is 60 %; cedar lumber is 67 %. The desired compressibility of the lumber 12 depends of kinds of lumber, but if the compressibility of the compressed lumber 20 is adjusted so as to make specific gravity 0.8 or more, flexural rigidity of the compressed lumber can be equal to or more than pure aluminum.

Note that, the compressibility of the compressed lumber 20 having thickness of "T" with respect to the non-compressed lumber 12 having thickness of "TO" is indicated by following formula: compressibility (%) = [(TO-T)/TO] x 100

The compressed lumber 20, whose compressibility reaches the prescribed value, is held in a compressed state in the compressing die 14, and the cut-end faces of the compressed lumber 20 are closed or covered by closing members 22 [see Fig. 2A], then a plurality of compressing dies 14, 14... is set in an electric furnace 24 so as to heat the dies [see Fig. 2B].

Unlike the case of wet-heating the compressing dies 14 by steam, the compressing dies 14 are dry-heated by the electric furnace 24 in the present embodiment, so the furnace need not be a pressure container and facility cost can be reduced.

Heating temperature and time are selected to permanently fix the compressed state of the compressed lumber 20. A relationship between the heating time and flexural rigidity of the compressed lumber varies as shown in Fig. 4: the flexural rigidity is made higher by heating; the flexural rigidity is gradually made lower by further heating after the flexural rigidity reaches the maximum value, and finally the lumber is carbonized.

Immediately after the flexural rigidity of the lumber reaches the maximum value, the compressed state of the lumber is permanently fixed. Temperature of heating the lumber is higher; required time to the maximum flexural rigidity is shorter.

Therefore, it is desirable to complete the heating step immediately after the flexural rigidity of the lumber reaches the maximum value. For example, in the case of heating the compressed lumber 20, which is white birch lumber and has size of 180 mm x 60 mm x 15 mm and the compressibility of 50 %, at 180° C, preferable heating time is about 120 min.; in the case of heating the compressed lumber 20, which is cypress lumber and has the same size and the compressibility of 50 %, preferable heating time is about 90 min..

When the compressing die 14 is dry-heated by the electric furnace 24, the compressed lumber 20 is compressed and heated in the compressing die 14, so the compressed lumber 20, which is air-tightly accommodated in the compressing die 14, can be wet-heated, even if the percentage of water content of the air-dried compressed lumber 20 is 12 %. This fact will be explained with reference to Fig. 5. Fig. 5 shows a

saturated steam curve; an area on the right side of the saturated steam curve is a superheated steam area; an area on the left side of the saturated steam curve is a wet steam area.

In the case of heating the compressed lumber 20, which has been formed by compressing air-dried lumber having the percentage of water content of 12%, at 180° C, if the compressibility (ε) is low, e.g., 25 %, the heating treatment is executed in the superheated steam area, so that the heating time to permanently compress the lumber must be longer. If the heating time is long, manufacturing efficiency of the compressed lumber must be low and properties of the compressed lumber, e.g., flexural rigidity, must be worse.

On the other hand, in the case of compressing and heating the compressed lumber 20, whose compressibility (ε) is high, e.g., 50 %, at 180 ° C, the heating treatment is executed in the wet steam area, so that the heating time to permanently compress the lumber is shorter than that in the superheated steam area. Since the heating time is short, the manufacturing efficiency of the compressed lumber can be higher and the properties of the compressed lumber, e.g., flexural rigidity, can be improved.

After the compressing die 14 is heated for a prescribed time, the compressing die 14 is cooled until the room temperature, then the die sections 16 and 18 are opened and the compressed lumber 26 is taken out [see Fig. 2C].

A boiling test of the compressed lumber 26 was executed, namely the compressed lumber was soaked in boiled water for a prescribed time, and form-recovery rate was about 10 %; in the case of air-drying the compressed lumber after the boiling test, the form-recovery rate was about 0 %, namely the shape of the compressed lumber returned to the shape prior to the boiling test. Therefore, the compressed state of the

compressed lumber 26 could be permanently fixed.

Further, the flexural rigidity of the compressed lumber 26 under an air-dried condition was 200 MPa or more. The flexural rigidity is equal to or greater than that of pure aluminum.

If the wooden plate 12 is made of white birch, larch, cypress, etc., which include resin, the compressed lumber 26, which is formed by compressing the wooden plate 12, is wholly colored dark brown. While the wooden plate 12 is compressed and heated, the resin in the wooden plate 12 wholly scattered and degenerated, so that the compressed lumber is colored dark brown. The degenerated resin is not oozed out from surfaces of the compressed lumber. Conventionally, larch lumber cannot be used for floor boards because a large amount of resin gradually ooze out from surfaces, but the resin in the lumber can be wholly scattered and degenerated by compressing and heating the lumber, so that the lumber including resin can be used for floor boards, etc.. Further, the degenerated resin acts as a reinforcing agent, so that rigidity of the compressed lumber 26 can be improved.

Some larch lumber have resin pools, but the resin in the resin pools can be scattered and degenerated, so only vestiges of the resin pools are left in the surfaces of the compressed lumber and no problems are occurred.

In the method of permanently compressing lumber shown in Figs. 1 and 2, the lumber was the wooden plate 12, but the lumber may be a log. In the case of compressing a log, rectangular lumber can be easily formed by compressing the log in two directions, which are perpendicular each other.

Damaged wood, whose edge portion includes many fine holes which are bored by pine bark and wood borers, etc., can be used for the wooden plate 12. The wooden plate cut from the damaged wood is a

porous wooden plate, which has the fine holes and whose density is low. The porous wooden plate can be formed into the compressed lumber by the compressing-and-heating method shown in Figs. 1 and 2. As shown in Fig. 6, a boiling test of the compressed lumber, which is made of damaged red pine lumber, was executed, namely the compressed lumber was soaked in boiled water for a prescribed time, and form-recovery rate was about 20 %; in the case of air-drying the compressed lumber after the boiling test, the form-recovery rate was about 0 %, namely the shape of the compressed lumber returned to the shape prior to the boiling test. Therefore, the compressed state of the compressed lumber, which is made of the porous lumber, could be permanently fixed.

Further, the flexural rigidity of the compressed lumber under the air-dried condition was 130 MPa or more as shown in Fig. 7. The flexural rigidity is equal to or greater than that of beech or zelkova lumber, so the compressed lumber made of porous wood can be used in many fields.

Since the porous lumber has many fine holes, the compressed lumber formed by compressing the porous lumber has high water absorptivity. Thus, fragrant lumber can be produced by impregnating aromatic essence into the fine holes.

In some damaged red pine lumber, holes bored by longicorn beetles or pine wood nematode exist, but the holes also can be closed by compressing and heating the lumber; the flexural rigidity can be nearly equal to that of beech or zelkova lumber.

The damaged lumber, which includes the holes bored by pine wood nematode, has almost no resin. So the compressed lumber, which is made by compressing and heating the damaged lumber, is colored brown, but some holes bored by pine wood nematode are highlighted. Preferably, the surfaces of the compressed lumber are colored dark brown so as not to

highlight the holes. To color the surfaces of the compressed lumber dark brown, time of heating the compressed lumber 24, which is air-tightly accommodated in the compressing die 14, is made longer. Further, in the case that the cut-end faces of the compressed lumber 24 are exposed in the air and the heating temperature and time are higher and longer (220 ° C, 5 hours) than those of the case in which the compressed lumber 24 is air-tightly accommodated and heated, the surfaces of the compressed lumber can be colored dark brown.

Damaged logs, which are damaged by pine bark and wood borers, also can be used in the present invention. In the case of compressing the damaged log, rectangular lumber can be easily formed by compressing the damaged log in two directions, which are perpendicular each other.

In the case of the rectangular lumber formed by heating and compressing the damaged login the two directions, the rectangular shape can be well kept and an outer portion of the compressed lumber is concentrically and uniformly compressed. In ordinary damaged wood, the fine holes are formed in an edge or outer portion and density of that portion is lower than a core portion, so compressing force is concentrated to the outer portion.

Porous wooden plates, which are made of the damaged wood, have high water absorptivity. So compressed lumber including the functional additive can be made by the steps of: absorbing suspension, which is formed by suspending the functional additive in alcohol, etc., into the fine holes of the porous wooden plate; and compressing and heating the porous wooden plate as well as the method shown in Figs. 1 and 2. Silica, alumina, lime, titanium oxide, glass, cement, etc. can be used as the functional additive for giving preservation property, durability and fire-resistivity. Further, compressed lumber, whose grains emit light in the night, can be made by impregnating a luminescence material into the

porous plate. The luminescence material may be impregnated together with the functional additive, e.g., silica. The functional additive, which has been suspended in solution, is impregnated into the porous wooden plate, then preferably the solution is evaporated to dry the wooden plate before compressing and heating the wooden plate. Therefore, volatile solution, e.g., ethyl alcohol, is preferably employed.

In the case of making the compressed lumber including the Functional additive, porous logs also can be used. In the case of compressing the porous log, rectangular lumber including the functional additive can be easily formed by compressing the porous log in two directions, which are perpendicular each other.

In ordinary damaged wood, the fine holes are formed in an edge or outer portion and density of that portion is lower than a core portion, but no fine holes are formed in the core portion, the functional additive is mainly absorbed in the outer portion of the wood. Therefore, the outer portion of the compressed lumber has various properties of the functional additive; the core portion of the compressed lumber acts as a tough core.

In the case of compressing the porous lumber too, the cut-end faces of the compressed lumber 24, which is compressed in the compressing die 14, may be exposed in the air, and the heating temperature and time may be higher and longer than those of the case in which the compressed lumber 24 is air-tightly accommodated and heated. With this manner, the surfaces of the compressed lumber can be colored dark brown, so that holes bored by pine wood nematode and faded resin portions can be disappeared.

In the present embodiment, the porous wooden plates and the porous logs are made of the damaged wood, in which fine holes are formed by pine bark and wood borers, etc., but the fine holes may be artificially formed.

EXPERIMENT 1

A wooden plate (cut from an outer portion of an air-dried white birch log) had a length of 180 mm, a width of 60 mm and a thickness of 15mm, and the wooden plate was set in the concave portion 17 of the female die section 16 of the compressing die 14. Cut-end faces of the wooden plate were exposed in the air; a whole bottom face and whole side faces of the wooden plate contacted the inner faces of the concave portion 17 without gaps.

Then the male die section 18 of the compressing die 14 was inserted into the concave portion 17 so as to compress a whole upper face of the wooden plate with a bottom pressing face of the male die section 18. The compressibility was 50 %. After the compressing action, the thickness of the compressed lumber was 1/2 of the thickness of the wooden plate not compressed. Then, the cut-end faces of the compressed lumber were closed by the closing members, and the compressed lumber, which was being compressed by the compressing die 14, was heated, at 180° C, for 120 min., in the electric furnace. After the heating step, the compressing die 14 was taken out from the electric furnace and naturally cooled, then the compressed lumber was taken out. The compressed lumber was colored dark brown.

Another compressed lumber was made by the same manner, but the heating time was 60 min.. The color of the compressed lumber was much lighter than the compressed lumber heated 120 min..

EXPERIMENT 2

Sample pieces of the compressed lumber of the EXPERIMENT 1 were made by cutting at positions 5 mm from the cut-end faces, and the sample pieces were dipped into boiled water as the boiling test. The results are shown in Fig. 8. As clearly shown in Fig. 8, the form-recovery

rate of the compressed lumber heated 120 min. was about 10 %, and a shape of the air-dried sample piece returned to the shape prior to the boiling test. Therefore, the compressed state of the compressed lumber was permanently fixed.

On the other hand, the form-recovery rate of the compressed lumber heated 60 min. was about 90 %, and the form-recovery rate of the compressed lumber air-dried after the boiling test was about 80 %. Therefore, the compressed state of the compressed lumber heated 60 min. was not permanently fixed.

EXPERIMENT 3

The compressed lumber was made as well as the EXPERIMENT 1, but the heating time was 90 min.. The color of the compressed lumber was dark brown, but the color was lighter than that of the compressed lumber heated 120 min..

The flexural rigidity of the compressed lumber, which was measured by static three-point bending test, was 200 MPa. The value is greater than that of pure aluminum.

EXPERIMENT 4

A wooden plate, which is cut from a core portion of cypress lumber, was compressed and heated as well as the EXPERIMENT 1, but the compressibility was 67 % and the heating time was 90 min.. The compressed lumber had dark brown color and a strong smell of the cypress. Results of the boiling test of the compressed lumber are shown in Fig. 9; the compressed state of the compressed lumber was fully fixed, and the flexural rigidity was 200 MPa.

EXPERIMENT 5

A wooden plate was cut from an outer portion of a red pine wood damaged by pine bark and wood borers. The wooden plate had a length of 180 mm, a width of 60 mm and a thickness of 15mm.

The wooden plate was set in the concave portion 17 of the female die section 16 of the compressing die 14. Cut-end faces of the wooden plate were exposed in the air; a whole bottom face and whole side faces of the wooden plate contacted the inner faces of the concave portion 17 without gaps.

Then the male die section 18 of the compressing die 14 was inserted into the concave portion 17 so as to compress a whole upper face of the wooden plate with a bottom pressing face of the male die section 18. The compressibility was 67 %. After the compressing action, the thickness of the compressed lumber was 1/3 of the thickness of the wooden plate not compressed. Then, the cut-end faces of the compressed lumber were closed by the closing members, and the compressed lumber, which was being compressed by the compressing die 14, was heated, at 180° C, for 90 min., in the electric furnace. After the heating step, the compressing die 14 was taken out from the electric furnace and naturally cooled, then the compressed lumber was taken out. The compressed lumber was colored dark brown.

The boiling test was executed as well as the EXPERIMENT 2, and the results are shown in Fig. 6. As clearly shown in Fig. 6, the compressed state of the compressed lumber was fully fixed.

Further, the flexural rigidity of the compressed lumber, which was measured by a static three-point bending test, is shown in Fig. 7. The flexural rigidity was 130 MPa., which is greater than the flexural rigidity of beech lumber and zelkova lumber.

EXPERIMENT 6

A red pine log, which had a bark and was damaged by pine bark and wood borers, was formed into rectangular lumber by compressing the log in two directions, which were perpendicular each other, then the compressing die, in which the rectangular compressed lumber was being compressed and cut-end faces of the compressed lumber were being exposed in the air, was heated at 220 °C for five hours. The outer portion of the rectangular compressed lumber, in which the fine holes were bored by pine bark and wood borers, etc., was uniformly compressed and had high density. Therefore, the damaged red pine wood can be used as the compressed rectangular lumber.

INDUSTRIAL APPLICABILITY

In the present invention, the lumber can be permanently compressed by compressing and heating the lumber without a drying step, so that manufacturing efficiency can be made higher and manufacturing cost can be reduced.

Damaged wood having many fine holes, which have been disused, can be effectively used as lumber.

Further, the compressed lumber can include the Functional additive, which have not been included in Conventional lumber, so the compressed lumber can be used in many new industrial fields.